Chapter 4B: STA Optimization

The Everglades Forever Act (EFA) requires the South Florida Water Management District (SFWMD or District) to optimize the nutrient removal performance of the Stormwater Treatment Areas (STAs). The STA Optimization Research and Monitoring Program consists of a number of individual research studies designed to assist the District in meeting this mandate. A description of this program and results from earlier STA optimization experiments and analyses can be found in previous Everglades Consolidated Reports (ECRs) (Chimney and Moustafa, 1999; Chimney et al., 2000; Nungesser et al., 2001; Jorge et al., 2002). The objective of this section of Chapter 4 is to summarize new findings and analyses completed since last year's 2002 ECR and to update on-going studies that provide new information, including STA optimization experiments conducted in the test cells. Evaluations of overall STA performance, including calculation of TP load and concentration reductions, are presented in section 4A of this chapter. This chapter (4B) contains performance evaluations of STA-1W, STA-5 and STA-6 and results from the final STA optimization experiments conducted in the STA-1 West (STA-1W) test cells.

PERFORMANCE EVALUATION OF STA-1W

DESCRIPTION OF STA-1W

STA-1W has five treatment cells organized into three separate treatment trains: east, west and north (**Figure 4B-1**). STA-1W's total area is 2,699 ha (6,670 acres). The older treatment trains, operational since 1994, consist of cells 1 and 3 (east) and cells 2 and 4 (west), respectively. Cells 5A and 5B (north), which began operation in late 1999, completed the STA-1W. Surface inflow to the wetlands originates at the S-5A pump station and enters STA-1W through the two at the G-302 lift gates. Part of the flow is directed westward through culverts in the G-304 levee, the primary inflow into the northern treatment train, while the rest flows through the G-303 gates into the eastern and western treatment trains. Water exits the northern treatment train through a series of 10 culverts in the G-306 levee and out of the STA through the G-310 pump station. Water from the eastern and western treatment trains exits through the G-251 pump station. Both flows are sent to Water Conservation Area 1 (WCA-1), which is the Arthur R. Marshall Loxahatchee National Wildlife Refuge.

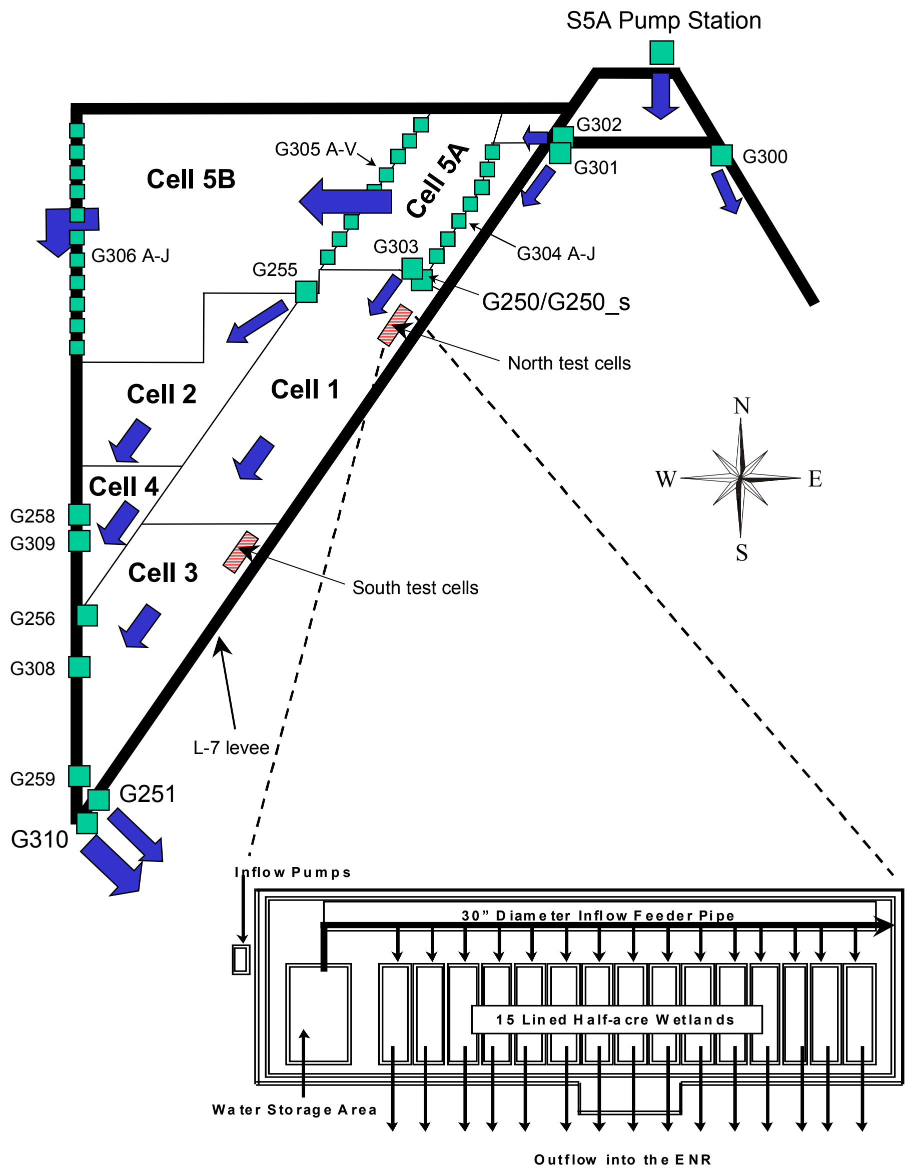

Figure 4B-1. Map of Stormwater Treatment Area 1-West showing location of the test cells. Arrows indicate direction of flow through each treatment cell.

Besides the engineered surface inflows into the STA, additional inflows include seepage from WCA-1 through the L-7 levee, groundwater upwelling and rainfall. Additional water losses include evapotranspiration, groundwater recharge and seepage into the seepage collection canals along the STA perimeter.

DATA COLLECTION AND ANALYSIS

Previous ECRs have included separate water and phosphorus (P) budgets for the older treatment cells in the STA and for the entire wetland (Chimney et al., 2000; Nungesser et al., 2001). This year's *2003 Everglades Consolidated Report* presents updated budgets for those treatment cells. Although cell 5 began discharging water in the summer of 2000, delays in instrumentation and its verification prevent calculating reliable water budgets. This year's water budget covers water year 2002 (WY2002) for cells 1 through 4. Water and phosphorus budgets for cell 5 will be provided next year for its period of record.

Water and phosphorus budget calculations followed the methodology detailed in Chimney et al. (2000) and Nungesser et al. (2001). Because STA-1W presents a significant departure from previous years' hydrology (described by Jorge et al. 2002), budgets are presented for the STA this year beginning only after modifications were completed (**Appendix 4B-1**).

The addition of two water control structures (G-308 and G-309) affected the water and nutrient budgets for cells 3 and 4. These new gates serve as separate outflow points for these cells, complicating the budgets' calculations. While flow data are available for each gate, TP concentrations have not yet been sampled. Evidence from tracer studies conducted in cell 4 indicated very short residence times for water when these large gates operate. Therefore, estimated TP concentrations for gates G-308 and G-309 were those for the cell 3 and 4 inflow levees, respectively.

RESULTS

Water Budgets

Inflow and outflow components of water budgets for STA-1W and its treatment cells during WY2002 are summarized in **Figure 4B-2**. Individual values for the water budget components are listed in **Appendix 4B-1**. Water budgets are calculated based on water years running from May 1 through April 30.

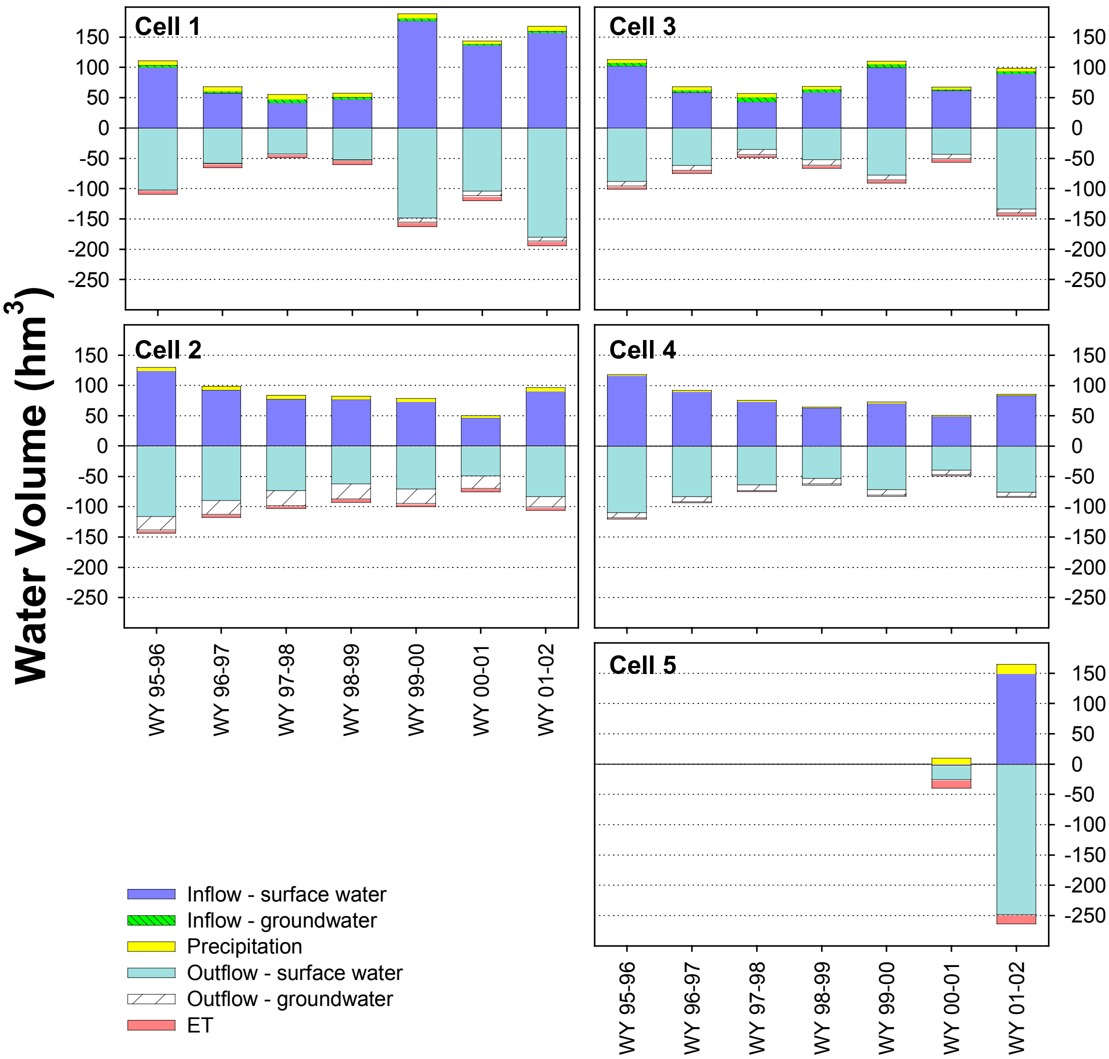

Figure 4B-2. Annual water budgets for each treatment cell in Stormwater Treatment Area-1W. Outflow components of each water budget are represented by negative water volumes. One hm^3 = 1,000,000 m^3.

STA-1W

The drought ended in WY2002, restoring a more normal hydrologic period for STA-1W than during the previous water year. Surface flow through G-302 conveyed 87 percent of the inflow, rainfall 11 percent, and seepage from WCA-1 accounted for 2 percent. Eighty-eight percent of outflow from the STA moved through pump station G-310, 2 percent through pump station G-251, evapotranspiration was 10 percent and groundwater recharge less than 1 percent. Total annual inflow during this water year was 334.4 hm^3 (1 hm^3 = 1,000,000 m^3), twice that of the prior year during the drought. The combined outflow pumping during WY2002 was also lower than in any previous water year, representing 90 percent of total outflow. Overall error for the STA-1W water budget has consistently remained at or below 5 percent, and this year's error term remained within this range at 3.6 percent.

CELL 1

Cell 1 receives all the inflow for the eastern and western flow-ways of STA-1W (**Figure 4B-1)**. Eighty-five percent of the total water volume into cell 1 enters through gate G-303 (**Figure 4B-2**). An additional 9 percent of inflow is delivered through pump station G-250s, which recycles water captured by the seepage canal of the STA. The remaining inflow was from rainfall (4.6 percent), seepage, and groundwater from WCA-1. Water entering through the pump station and gate is routed in nearly equal proportions either southward through cell 1 (46 percent) or westward through the G-255 levee into cell 2 (47 percent). Evapotranspiration accounted for another 4 percent of water leaving the treatment cell. Seepage and groundwater recharge made up the other 3 percent of the outflow from cell 1. As in the previous water year, the annual water budget error was larger than earlier in this treatment cell's history (-16 percent).

CELL 2

Cell 2 is the northern treatment cell for the western flow-way of STA-1W (**Figure 4B-1**). Ninety-four percent of inflow was through G-255 from cell 1, 91 million cubic meters (**Figure 4B-2)**; six percent of the water fell as rain. Outflow from cell 2 through G-254 into cell 4 accounted for 79 percent of outflow. An additional five- percent of outflow was from evapotranspiration and 16 percent from seepage into the seepage return canal. The water budget for cell 2 continued to reflect relatively high error, averaging -11.3 percent for WY2002, but considerably less than last year's high of nearly 50 percent error in the budget.

CELL 3

Water leaving cell 1 flows into cell 3 through the G-253 levee (**Figure 4B-1**) and was 91 percent of the annual total inflow (**Figure 4B-2**). Seepage from WCA-1 and groundwater provided another 4 percent, with rainfall accounting for the remaining 5 percent. Originally, outflow from cell 3 was not measured directly as in the other treatment cells. Surface outflow was estimated as the difference between outflow pumped through G-251 and the outflow from cell 4 that was conveyed to G-251 (outflow 3 = G-251 – G-256). Operation of the new G-308 structure has changed the outflow path, altering cell 3 outflow estimates. The combined water volumes for these two structures accounted for 76 percent of the outflow. Evapotranspiration and seepage accounted for 11 percent each, with the remaining 2 percent through groundwater recharge. The water budget error for cell 3 was high at 50 percent, probably because of error in the two outflows. Previous years' water budget error ranged between 1 and 15 percent.

CELL 4

Surface water enters cell 4 through the G-254 levee from cell 2 (**Figure 4B-1**). This levee provided 98 percent of the inflow (**Figure 4B-2**), with the additional water as rainfall (2 percent). Outflow is more complex. The new gated structure G-309 was used occasionally during the year, removing 23 percent of the outflow. Most outflow passed through the G-256 levee (67 percent), with additional outflow as evapotranspiration (2.3 percent) and seepage (7.5 percent). Unlike the other treatment cells, residual error in cell 4's water budget was extremely low this year, less than 1 percent.

CELL 5

Inflow into cell 5 is through the G-304 levee, paralleling the canal between the STA inflow gate G-302 and the G-303 gate (**Figure 4B-1**). Water travels westward through the G-304 levee, moving westward through an interior levee and out through the G-306 levee into the western discharge canal. From there, cell 5 water is pumped out of STA-1W through pump station G-310 into WCA-1. Based on preliminary data, it appeared that 91 percent of the inflow was through the

G-304 levee and 9 percent from rainfall (**Figure 4B-2**). Outflow was through the G-306 levee (94 percent), with an additional 6 percent from evapotranspiration. Estimates of inflow through G-304 are inaccurate, so instrumentation is being verified. When the revised data are available (anticipated by August 2002), the cell 5 water budget will be recalculated.

Phosphorus Budgets

Total phosphorus (TP) retention varies among treatment cells, but overall, STA-1W retained 71 percent of incoming TP for WY2002 (see section 4A of this chapter). This year's cell treatment performance has remained generally consistent with prior water years in retention but not in outflow concentrations, which have experienced their third year of increased outflow concentrations. The cells retained TP over a wide range of flow conditions and operational practices, including high and extended low-flow periods. The highest treatment efficiencies coincided with high flow during the summer of 2001, when the drought broke and normal rainy season conditions prevailed. For several months, Cells 1, 2, and 3 exported rather than retained TP, but this pattern corrected itself over the water year. Outflow TP concentration from Cell 4 has continued to increase since its lows in WY1998 and 1999, currently averaging 33 µg/L for WY2002. For this water year, Cells 1 through 4 retained 42,380 kg. Individual treatment cell TP budgets are shown in **Appendix 4B-2**.

CELL 1

For the period of record, Cell 1 has retained approximately a third of all incoming TP (**Figure 4B-3**); however, during WY2002, it retained only 22 percent of incoming TP, totaling 3,482 kg TP. The cell's average TP reduction was 0.860-g/m^2·yr. Flow-weighted TP concentrations decreased from 95.4 µg/L at the inflow to 64.4 µg/L at the Cell 1 outflow.

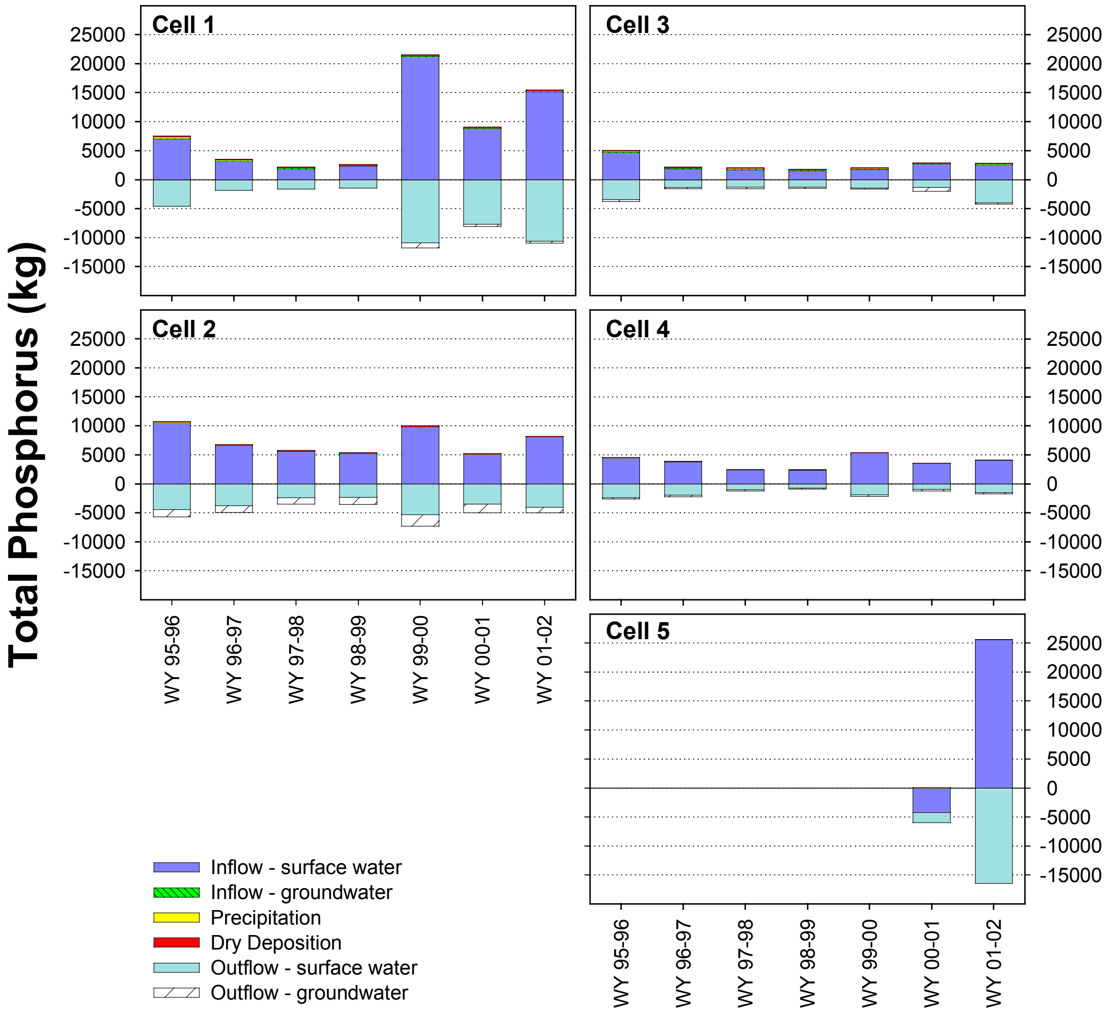

Figure 4B-3. Annual total phosphorus budgets for each treatment cell in Stormwater Treatment Area 1-W. Outflow components of each TP budget are represented by negative values.

CELL 2

Cell 2 retained 23 percent of inflow TP from all sources (**Figure 4B-3**), 2,302 kg TP for WY2002. TP load reduction averaged 0.492 g/m^2·yr for this wetland. Similar to Cell 1, inflow TP concentrations from all sources was 91.4 µg/L, decreasing to 63.8 µg/L at the outflow.

CELL 3

Conversion to STA operations altered the outflow regime and complicated calculations for treatment Cell 3. Because outflow is calculated instead of measured directly, a number of assumptions necessarily were made regarding both outflow volume and outflow TP concentrations. When the G-308 gate operated, water was pulled from both Cell 3 and from the outflow canal flowing from Cell 4. The G-308 gate operated during most months of WY2002. Because TP loads were calculated based both on concentrations and water volumes, significant uncertainties in outflow water volumes and TP concentrations make the Cell 3 TP budgets unreliable.

CELL 4

Cell 4, managed for submerged aquatic vegetation, has continued its high overall TP retention of 51 percent (2,896 kg TP) for this water year (**Figure 4B-3**). TP load reduction averaged 1.971 g/m^2·yr, considerably higher than cells 1 and 2. However, cell 4 outflow concentrations have increased over the last three years, double that of its optimal period from WY1998 to WY1999. WY2002 flow-weighted TP concentrations decreased from 66 µg/L at the inflow to 33 µg/L at the cell 4 outflow. Prior year outflow concentrations were 27 µg/L in WY2001and 27 µg/l in WY2000. Reasons for these increased outflow concentrations are not clear but are being investigated.

CELL 5

Calculating a TP budget for cell 5 requires a good water budget. When the water budget issues are resolved, the cell 5 TP budget will be produced.

FUTURE MONITORING

The District recognizes that error in the water and TP budgets for several STA-1W treatment cells is high. To reduce these errors, the District is re-surveying the head and tailwater elevations for G-302, G-303, G-308, G-309 and all water control structures within cell 5 (**Figure 4A-1**). These new elevation data will be used to verify stage calculations and flow equations associated with these structures and to correct flow estimates. In addition, the District will install autosamplers at G-302, G-304, G-306, G-308, and G-309 to collect time- or flow-proportioned samples to improve estimates of TP concentrations at these structures. Future Consolidated Reports will include water and phosphorus budgets for all five treatment cells of STA-1W.

STA-1W TEST CELL RESEARCH

DATA COLLECTION AND ANALYSIS

The District is conducting research in the STA-1W test cells to evaluate the impact that hydrology has on wetland performance as part of the STA Optimization Research Program. These experiments involve hydraulic manipulations, such as maintaining steady flows and depths for a prescribed period, that cannot be duplicated in the STAs because the timing and delivery of water to the STAs is a function of rainfall events and subsequent flood control discharges from the drainage basin that cannot be controlled to the degree needed for these experiments.

The test cells are small, rectangular wetlands that encompassing 0.2 ha each and are hydrologically isolated from each other. The test cells are arranged into two groups of 15: one group in cell 1 and the other in cell 3 of STA-1W (**Figure 4B-1**). Ten test cells are being used for this research: six at the north site and four at the south site. Vegetation in the test cells consists primarily of dense stands of cattail (*Typha* spp.) mixed with incidental populations of submerged aquatic vegetation (SAV) and periphyton. The District elected to perform this research in cattail-dominated systems that developed voluntarily because it is anticipated that this community type will also dominate the STAs. A more complete description of the test cells and the design of the individual experiments being conducted in them is provided in previous ECRs (Chimney et al., 2000; Nungesser et al., 2001). The status of STA optimization experiments scheduled for the test cells is provided in **Table 4B-1**. Findings from hydraulic loading rate (HLR) experiments that concluded in WY00–01 are described in last year's ECR (Jorge et al., 2002). The treatment effi cacy of wetlands dominated by SAV and periphyton is being evaluated in other District-sponsored research projects (see section 4C of this chapter).

Table 4B-1. Experiment start dates, mean hydraulic loading rates, and nominal depths for STA Optimization research experiments conducted in the STA-1W test cells. Two control test cells at each the North and South sites were held at a constant HLR of 2.3 cm/d and nominal depths of 0.6 m for all experiments. Test cells were operated in one of the following sequences: Low HLR-Low Depth-High Depth or High HLR-Pulsed flow

				HLR (cm/d)		
Exp. #	**North Test Cells**	**South Test Cells**	**Regime**	**Low**	**High**	**Depth (m)**
1	May 19, 1999	November 2, 1999	HLR	1.2	4.8	0.6
2	September 1, 1999	February 14, 2000	HLR	0.1	10.4	0.6
3	February 14, 2000	July 5, 2000	HLR	0.3	18.5	0.6
4	October 4, 2000	October 18, 2000	Pulsed	0.05 - 5.1		0.6
5	October4, 2000	October 18, 2000	Depth	2.6		0.2
6	July 24, 2001	July 24, 2001	Pulsed	0.3 - 15.3		0.6
7	July 24, 2001	July 24, 2001	Depth	2.6		1.2

One series of experiments concluded in WY01–02 was designed to document the effect that water depth has on P removal (**Table 4B-1**). All test cells used in these experiments were operated initially at an HLR of 2.6 cm/d and a depth of 0.6 m to provide baseline performance data. These starting conditions were within the range of the STA conceptual design criteria (1.6 ≤ HLR ≤ 3.0 cm/d; 0.2 m ≤ operating depth ≤ 1.4 m; Burns and McDonnell, 1994) and operating guidelines currently used for the STAs. Two test cells at each location acted as controls and were maintained at the initial HLR throughout the experiments (NTC-05, NTC-10, STC-01 and STC-15). Two north cells (NTC-07 and NTC-08) and one south cell (STC-01) were used for water depth experiments (nominal low depth = 0.15 m; high depth = 1.2 m) and were operated at a constant HLR of 2.6 cm/d. Actual depths were recorded throughout the study every 10 m along a centerline transect from inlet to outlet. At constant HLR, depth is proportionately related to the nominal hydraulic retention time (HRT), i.e., decreasing the depth decreases the HRT, and increasing the depth increases the HRT. To determine actual HRTs, lithium (Li) tracer experiments were conducted in five test cells for each of the low- and high-depth experiments.

Concurrent with the depth experiments, pulsed HLR experiments were conducted in the remaining STA optimization test cells (**Table 4B-1**). The HLR in the pulsed experiment was changed biweekly and varied from 0.05 to 15.27 cm/d. The flow pattern developed for this experiment was based on a 10-year period of record (1978 to 1988) for the STA-2 basin. The pulsing experiment was conducted for one calendar year that extended from October 2000 through September 2001 and included Florida's wet and dry seasons. The wet season generally runs from May through October and the dry season runs from November through April. During these experiments, District personnel were able to examine effects of pulsing according to both a high and a low HLR regime. The low-pulsed regime ran from October 2000 through April 2001, and then increased from May 2001 through the end of October 2001. During the low-pulsed period, HLR ranged from 0.05 to 5.1 cm/d; HLR ranged from 0.3 to 15.3 cm/d for the high-pulsed period.

RESULTS

The pulsed and the low- and high-depth experiments were concluded in WY01–02 (**Table 4B-1**). These experiments were conducted to help answer two questions central to the STA Optimization Research Program, those being, what are the impacts of prolonged low or high depth on treatment performance of the STAs, such as that which might occur during extremely dry or wet periods, and what are the effects of pulsed inflow on treatment performance? The reader is cautioned that results from these experiments can only be extrapolated to full-scale wetlands with the same type of vegetation, i.e., cattail-dominated communities, and are subject to the scaling artifacts inherent in all small-scale ecological experiments discussed in Jorge et al. (2002).

Low-depth Experiments

The mean water depth at the north site was 0.28 m (NTC-07) and 0.31 m (NTC-08) for the low-depth cells and 0.79 m (NTC-05) and 0.86 m (NTC-10) for the control cells, which was higher than nominal depths calculated from mean water stage and the design sediment elevation. This resulted in actual mean HRT calculated from tracer studies of 9.5 days for the low-depth cells and 36 days for the control cells. At the south site, measured depths more closely matched nominal depths, with means of 0.15 m for the low-depth cell (STC-02) and 0.6 m for the control cell (STC-01), respectively. Correspondingly, mean HRTs at the south site were four days and 28 days for the low-depth and control cells, respectively.

The mean inflow TP concentration at the north site was 45 µg/L, which was almost twice the mean TP inflow of 19 µg/L at the south site. The north control cells reduced the inflow TP concentration by about 55 percent, while the south control cells experienced only a slight 6 percent reduction.

Dropping the depth to nominal 0.15 m resulted in a slight improvement in TP removal at the north site, but showed significantly poorer P removal performance in the south site compared to the respective controls. The mean outflow TP concentrations at the north control and low-depth test cells were 16 versus 20 µg/L, respectively. In the south, mean outflow TP concentration in the low-depth cell was 38 µg/L and 18 µg/L in the control systems.

High-depth Experiments

The actual mean water depth at the north site was 1.29 m (NTC-07) and 1.31 m (NTC-08) for the high-depth cells, and 0.79 m (NTC-05) and 0.86 m (NTC-10) for the control cells, which are higher than the nominal depths calculated from mean water stage and design sediment elevation. This resulted in actual mean HRT calculated from tracer studies of 55 days for the high-depth cells and 36 days for the controls in the north. At the south site, measured depths more closely matched nominal depths, with means of 1.2 m for the high-depth (STC-02) and 0.6 m for the control cell (STC-01), respectively. Correspondingly, mean HRTs at the south site were 50 days and 28 days for the high-depth and control cells, respectively.

During the high-depth experiments, mean inflow TP concentration at the north site was 77 µg/L, which was slightly more than twice than the south site's 35 µg/L. During the experiment, the north control cells reduced inflow TP concentration by about 66 percent, while the south site controls showed a mean TP concentration reduction of only 12 percent.

Increasing water depth in the north site had no effect relative to controls, with mean outflow TP concentrations of 26 and 28 µg/L for the control and high-depth systems, respectively. However, during the first seven weeks of this study the high-depth system showed outflow TP concentrations that generally exceeded those of the control systems.

At the south site, the mean control TP outflow concentration was 30 µg/L, which was slightly less than the mean inflow TP concentration; however, as has been commonly found at the South site, outflow TP concentrations in these test cells often exceeded inflow TP concentrations (35 µg/L) during the experiment. The mean outflow TP concentration for the high-depth system was 110 µg/L, which far exceeded the mean inflow TP concentration. However, the outflow mean was strongly influenced by extremely high outflow TP concentrations during the first seven weeks of the experiment. Following this period, the outflow TP concentration of the high-depth cell dropped and remained relatively stable, with a mean concentration of 41 µg/L for the remainder of the experiment.

Pulsed Experiments

The overall mean HLR to the pulsed systems at both the north and south sites was 3.4 cm/d. This was higher than in the controls and STA design HLRs (1.6 to 3.0 cm/d; Burns and McDonell, 1994) due to the constraints of the orifice sizes for inflow pipes. To mimic increased flows expected during the wet season, the HLR during this period was varied from 0.72 to 18.5 cm/d, with a mean of 5.4 cm/d. The mean HLR during the dry season part of the study was 1.4 cm/d and ranged from 0 to 4.8 cm/d (**Figure 4B-4**).

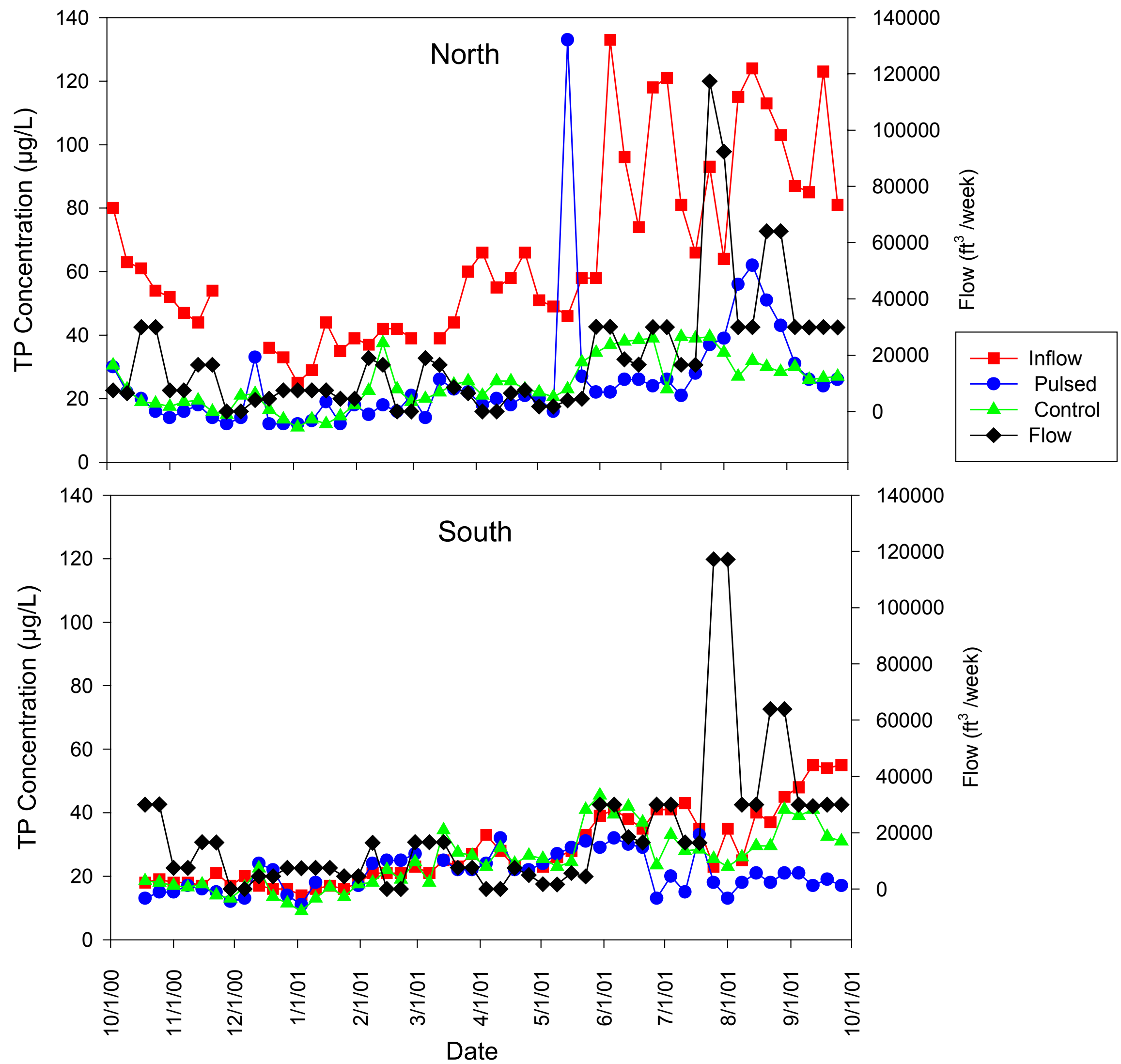

Figure 4B-4. Inflow, pulsed outflow and control outflow total phosphorus concentrations for the pulsed-HLR experiments at the north and south test cells located in STA-1W (October 4, 2000–October 3, 2001).

The mean inflow TP concentration at the north and south sites during this study (October 2000 to October 2001) was 66 and 28 µg/L, respectively. However, mean TP inflow concentration at both sites was significantly lower during the dry season than the wet season (**Figure 4B-5)**.

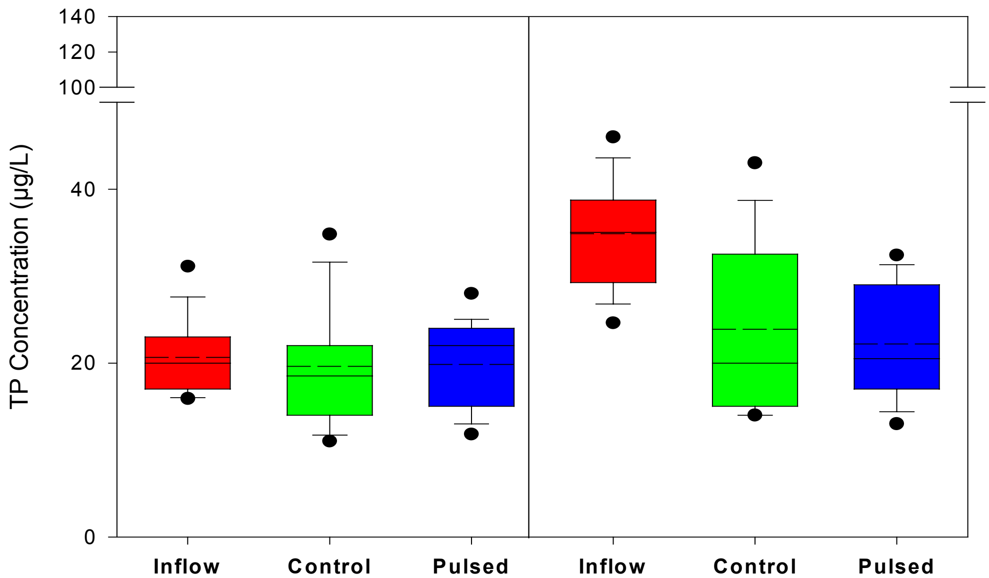

Figure 4B-5. Inflow, control outflow and pulsed outflow during dry and wet season pulsing regimes for north and south sites. HLR ranged from 0-4.8 for the dry and 0.72 - 18.5 for the wet season.

Generally, TP outflow concentrations for the pulsed and control systems at the north site were below inflow TP concentrations, with means of 40 and 25 µg/L, respectively **(Figure 4B-5)**. While mean TP outflow concentrations for both controls and pulsed systems were greater during the wet season pulsing regime than during the dry season, mean TP concentration reduction was greater in the wet season due to increased inflow TP concentration during this time period.

At the south site, mean outflow TP concentration from the pulsed cell was 20 µg/L, slightly less than the control cell mean of 26 µg/L. The mean outflow from both systems was less than the mean inflow TP concentration (**Figure 4B-5**). As at the north site, the mean outflow TP concentration was higher during the wet season than the dry season although the percent reduction increased due to increased inflow TP concentrations.

Hydraulic Tracer Studies

Uneven flow patterns through a treatment wetland, i.e., short-circuiting, can result in hydraulic inefficiency and might reduce the systems ability to remove nutrients and other constituents (Reed et al., 1995; Persson et al., 1999). Hydraulic tracer studies are the most effective means to quantify the degree of wetland short-circuiting. District staff conducted a number of tracer studies using lithium (Li) in five STA optimization test cells between May 2000 and August 2000 as part of the HLR experiments (**Table 4B-1**). These data were reported in Jorge et al. (2002). Staff subsequently conducted eleven additional tracer studies in six of the STA optimization test cells between March 2001 and February 2002 as part of the water depth experiments described above. Tracer spikes were prepared by diluting Li chloride brine solution (78,457 mg/L as Li) to an approximate concentration of 350 µg Li/L. The tracer spike was added to each test cell over a period of two minutes by pouring it into the inlet distribution system. Automated samplers were deployed at the outlet of each test cell and programmed to collect 250-mL samples at varying time intervals, beginning with the introduction of the tracer. Samples were preserved with nitric acid (pH ≤ 2). Test cell outflow rates were measured daily as described in Chimney et al. (2000).

The tracer study data were interpreted following the gamma distribution method summarized by Kadlec (2001). Each hydraulic tracer study was typically run for a period three times the nominal HRT to ensure adequate recovery of the Li spike. The mean τ for the 11 systems ranged from a low of 4.2 d for test cell STC-02 when operated at a depth of 0.15 m, to a high of 55.7 d for test cell NTC-07 when operated at a depth of 1.2 m (**Tables 4B-2** and **4B-3**). The residence time distribution (RTD) curves for all the tracer-tested systems fell into two general groups. Five of the studies tended toward plug-flow hydraulics with an N greater than 4.0; the remaining six studies had an N of less than 3.0 (**Figure 4B-6**). With the exception of one system, the emergent systems with cell depth greater than 70 cm tend to exhibit better plug-flow hydraulics than systems with depths less than 60 cm.

Table 4B-2. Summary of lithium tracer studies performed at the STA Optimization Test Cells located within STA-1W, cells 1 and 3. Tracer tests were performed during the low-depth experiments from 1 March 2001 to 30 June 2001.

	North Test Cells			South Test Cells		
Parameter	**Control**	**Low-depth**	**Low-depth**	**Control**	**Control**	**Low-depth**
Test cell number	NTC-05	NTC-07	NTC-08	STC-01	STC-15	STC-02
Mean volume (m^3)	1,961	646	719	1,423	1,906	340
Mean flow (m^3/d)	57.4	60.8	59.6	61.1	61.4	63.6
Mean HLR (cm/d)	2.6	2.6	2.6	2.6	2.6	2.6
Mean depth (cm)	78.7	28.2	31.4	58.9	76.6	15
Nominal HRT (d)	34.2	10.6	12.1	23.3	31.0	5.3
Mean HRT, τ (d)	34.9	9.9	9.1	28.1	38.1	4.2
Number of tanks (N)	4.61	2.3	2.6	1.6	1.9	2.8
Mass recovery (%)	46.5	76.4	62.8	19.7	32.2	83.7
Hydraulic efficiency (%)	102	93	76	121	123	79

Table 4B-3. Summary of lithium tracer studies performed at the STA Optimization test cells located within STA-1W, cells 1 and 3. Tracer tests were performed during the high-depth experiments from 2 November 2, 2001 to February 24, 2002.

	North Test Cells			South Test Cells	
Parameter	**Control**	**High-depth**	**High-depth**	**Control**	**High-depth**
Test cell number	NTC-05	NTC-07	NTC-08	STC-01	STC-02
Mean volume (m^3)	1,961	3,013	3,495	1,314	3,153
Mean flow (m^3/d)	69.7	69.6	70.2	66.7	67.4
Mean HLR (cm/d)	2.6	2.6	2.6	2.6	2.6
Mean depth (cm)	78.7	129.3	131.4	54.8	120
Nominal HRT (d)	28.2	43.2	49.8	19.7	46.8
Mean HRT, τ (d)	49.7	55.7	55.1	21.9	50
Number of tanks (N)	4.6	5.8	4.5	2.4	4.8
Mass recovery (%)	58	61.6	58.1	5.8	68.3
Hydraulic efficiency (%)	177	129	111	111	107

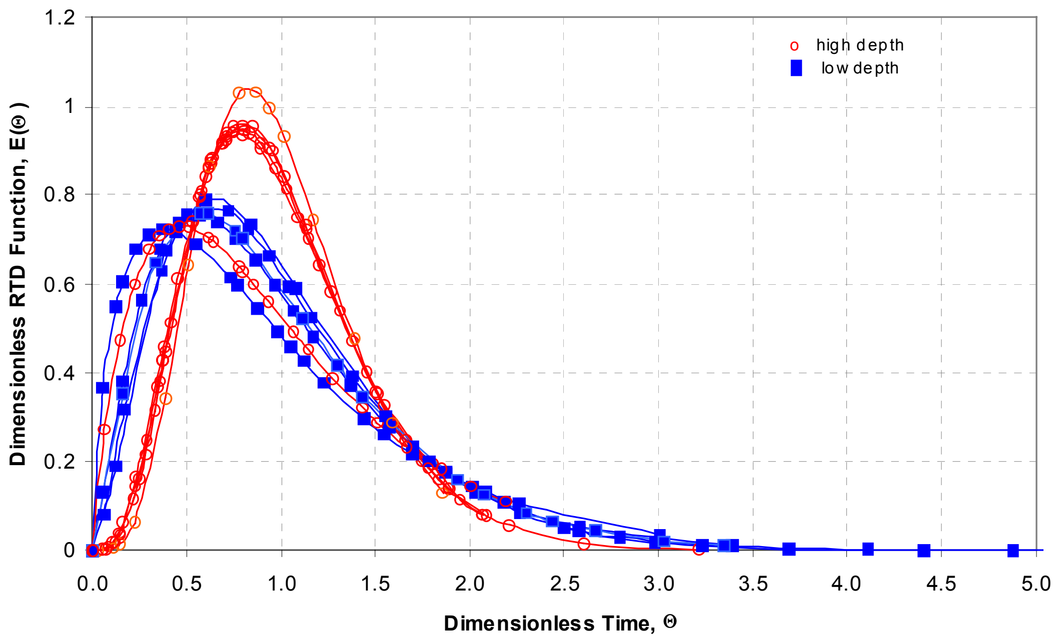

Figure 4B-6. Residence time distributions for the north and south test cells generated using the gamma distribution method. Tracer data were collected during the high and low depth STA Optimization experiments from March 1, 2001 to February 24, 2002. Blue solid squares denote cell depth higher than 70 cm and red open circles denote cell depths less than 60 cm.

The mean HRT based on the tracer data for test cell NTC-05 was about the same as the nominal HRT computed using the HLR, indicating that this system probably did not have many dead zones or major short circuits (Levenspiel, 1999). However, the three low-depth systems (NTC-07, NTC-08, and STC-02) had mean tracer HRTs that were less than the calculated nominal HRT, indicating possible dead zones within the system. The two south control wetlands (STC-01 and STC-15) had mean tracer HRTs greater than the calculated nominal HRT. Tracer HRTs greater than the nominal HRT could indicate either that part of the system volume was not used in the movement of the tracer (i.e., it was bypassed) or that there was an inaccurate average bottom elevation, leading to an incorrect volume estimate (Kadlec, 1994).

Percent mass recovery of tracer ranged from a low of 20 percent to a high of 84 percent (**Tables 4B-2** and **4B-3**). Low tracer recovery is generally indicative of seepage loss or decay/adsorption/absorption of the tracer material. However, the test cells are fully lined and have no leaks, and Li is not thought to be subject to absorption, adsorption or decay. One theory is that there might have been entrapment of some Li directly in the sediment due to the method of tracer addition (R. Kadlec, personal communication). Lithium is more dense than water, and it is possible that the method of introduction to the test cells, i.e., poured as a steady stream over a two-to-three-minute duration into the influent distribution trough, may have resulted in a portion of the Li sinking into the sediment at the base of the inlet distribution trough. If this were true, it would follow that the shallower test cells would have entrapped more of the Li. However, the three low-depth systems (NTC-07, NTC-08 and STC-02) had the best tracer recoveries. Additionally, in conjunction and concurrent with the Li tracer study, the District participated with DB Environmental, Inc. in a comparative study of rhodamine WT dye and bromide tracers to determine if either of these materials could be used in place of Li in an emergent cattail system. Two of the control test cells, one at the north site (NTC-05) and one at the south site (STC-01), were used in this study. Concurrent with the Li addition described above, rhodamine WT and bromide were added as dilute solutions in a similar manner to the Li tracer previously described. At the north site (NTC-05), the mass recovered for the bromide and rhodamine WT was less than that for the Li, with 23 percent and 16 percent recovered, respectively. At the south site (STC-01), the bromide mass recovery was only slightly better than that of the Li (23 percent), while 41 percent of the rhodamine was recovered. While the results of this comparative study were inconclusive regarding mass recovery efficiency comparisons with respect to Li, the study results indicated that, regardless of the mass recovered, the results of the mean tracer HRT and tank-in-series calculations are relatively similar, and the main trend was the same, with NTC-05, but not STC-01, tending toward plug-flow hydraulics.

MANAGEMENT IMPLICATIONS

Increasing or decreasing the depth of the test cell while maintaining the HLR had only a slightly positive effect on the TP removal performance of the north site wetlands. Therefore, in this study, neither increasing or decreasing the HRT of the system by more than half had the same effect as during the HLR experiment, where a marked increase in mean TP outflow concentration compared to controls was noted when HRTs were lowered to less than 11 days, but not when HRT was increased (Jorge et al., 2002). The two main differences between these experiments were that the depth was changed and the mass TP load was constant on an areal basis. During the HLR experiment, the areal TP load was greatly modified in both directions. Additionally, during the low- and high-depth experiments the overall mean inflow TP concentration was 45 µg/L, which is less than half the mean TP inflow concentration of 100 µg/L during the HLR experiment. Therefore, in front-end emergent STA cells, it appears that changes in depth does not need to be an operational constraint, because the loading rate is the greater determining factor in system performance.

Conversely, increasing or decreasing the depth while maintaining the HLR at the south site had negative effects on TP removal performance compared to the control systems. During both the HLR and depth experiments, the test cells exhibited little or no TP removal capabilities due to the extremely low inflow TP concentrations at this site. Therefore, it appears that emergent cells may not be efficient in TP removal when functioning as the last ‘polishing’ cell in a treatment train.

While pulsing in both the north and south site test cells during the dry season resulted in slightly greater lowering of TP removal compared to controls during the wet season, overall pulsing did not have a significant negative effect on TP removal performance from these wetland systems.

FUTURE MONITORING

Forecasts of STA performance based on this work must be verified against actual STA performance data. It should be noted, however, that the unifying principle behind all these experiments was to examine wetland response at the extremes of STA operating conditions. Verification will be possible only when the STAs experience extreme hydrologic conditions. Comparisons between predicted and actual STA performance will be made in future Everglades Consolidated Reports, as the requisite data become available.

PERFORMANCE EVALUATION OF STA-2

Instruments to monitor flow and water quality conditions are currently being installed at interior sites within STA-2. The District has initiated sediment, vegetation and "grab" water quality sampling within each treatment cell. Analyses of these data will be presented in the *2004 Everglades Consolidated Report*. Please refer to Chapter 4A of this report for information regarding STA-2 permit compliance.

PERFORMANCE EVALUATION OF STA-5

STA-5 encompasses an area of 1,975 ha (4,880 ac), with an effective treatment area of 1,663 ha (4,109 ac). This STA is located in Hendry County, east of the L-2 borrow canal and west of the Rotenberger Wildlife Management Area (**Figure 1-1**) and is divided into parallel north and south flow-ways, each with two treatment cells (**Figure 4A-12**). The northern and southern flow-ways are equal in area, each encompassing about 832 ha (2,055 ac). The front 156 ha (385 ac) of each flow-way are not flooded. Therefore, cells 1A and 2A have an effective treatment area of just 338 ha (835 ac). STA-5, cells 1B and 2B are larger, with each having an effective treatment area of 494 ha (1,220 ac). Refer to the STA-5 Operation Plan (SFWMD, 2000b) and both the 2001 and *2002 ECR* for a detailed description of STA-5 operations. Section 4A of this chapter discusses current performance data.

From startup through WY01-02, STA-5 has experienced dryout several times in response to no-flow conditions associated with the severe drought in South Florida from December 2000 until June 2001. All cells in STA-5 during this time experienced belowground water depths for days 105 through 156, except for STA-5, cell 1B, which remained flooded because a temporary inflow pump provided water to sustain the SAV community. In response to these dryout events, the District initiated a six-month monitoring study that began in June 2001, to evaluate changes in the plant community and water quality within STA-5.

DATA COLLECTION AND ANALYSIS

As part of the ongoing STA optimization program, the District began conducting yearly monitoring of internal (cell-to-cell) P reduction, sediment nutrient content, and vegetation species' presence and abundance in STA-5 to fully assess, and then optimize, the P-removal efficiency of each treatment cell. In addition, the worst drought in South Florida's recorded history ended in 2002, and the District initiated a study to evaluate the potential for nutrient release from dried STA-5 soils upon reflooding. This year's ECR presents the results of these various monitoring efforts. Evaluations of overall STA P removal performance, including calculation of TP load and concentration reductions, are presented in Chapter 4A.

METHODS

Weekly composite flow-weighted water samples are collected and analyzed for TP concentration from STA-5 inflow structures G-342A through D, and outflow structures G-344A through D, for permit compliance (see Chapter 4A). In addition, biweekly grab samples are collected from these structures and are analyzed for soluble reactive (SRP), total dissolved P (TDP), nitrate+nitrite nitrogen (NO_x-N), ammonia nitrogen (NH_4-N), total Kjeldahl nitrogen (TKN), total dissolved Kjeldahl nitrogen (TDKN), chloride (Cl), sulfate (SO_4), alkalinity, pH, dissolved oxygen (DO), conductivity, and temperature. Additionally, at the end of April 2002 the District installed autosamplers at two internal flow-way structures (G-343B and G-343F), located between the upper and lower treatment cells in the north and south flow-ways.

Beginning in June 2001, 12 sites in each treatment cell (48 total sites) were monitored semi-annually to ascertain community composition and vegetation re-growth following the drought. At each site, vegetation percent cover and species composition was recorded within a 1-m2 plot. Samples from a 0.25 m^2 quadrant of the dominant species within each treatment cell were collected at or near the vegetation survey sites and were analyzed for TP, total carbon (TC), total nitrogen (TN), and dry-weight content. Additionally, soil and water depths were measured at each site with a calibrated metal rod and meter stick, respectively. Nominal cell water depth within STA-5 was calculated by subtracting the mean cell bottom elevation from the mean stage levels recorded at the inflow, outflow and middle levee.

Daily average flow at pumps G-349A, G-349b, G-350A and G-350B were computed using pump revolutions and headwater/tailwater stage data. Daily average flow through culverts G-342A through D, and G-344A through D were computed using combination culvert/orifice equations for each structure based on gate opening and headwater/tailwater stage data.

RESULTS

Hydraulic Performance

Mean nominal water depths for WY01-02 were 0.53 m and 0.41 m for the northern and southern flow-ways, respectively. These depths were higher than mean flow-way depths for WY00-01, especially in the southern flow-way (STA-5, cells 2A and 2B), which was not kept hydrated during the drought in WY00-01. Except for STA-5, cell 2A, the measured mean depths of each cell were about equal to or greater than the nominal depth, with mean depth differences ranging from about 1 cm to 15 cm, mainly due to a series of deep zones that exist in the most eastern section of STA-5, cells 1A 1B.

Average annual inflow during WY01-02 for both flow-ways was approximately 101 hm^3/yr, which was slightly more than the original design flow of 96.7 hm^3/yr, but less than the estimated flow of 128.4 hm^3/yr when accounting for the additional water from the Deer Fence Canal. Outflow for the northern flow-way was 62 hm^3/yr greater than the southern flow-way. Monthly inflows ranged from zero flow during the dry season to approximately 22 hm^3/mo during the wet season. During WY01-02, about 90 percent of the flow occurred between May and December 2001, indicating the highly pulsed nature of the water delivery (**Figure 4B-7)**.

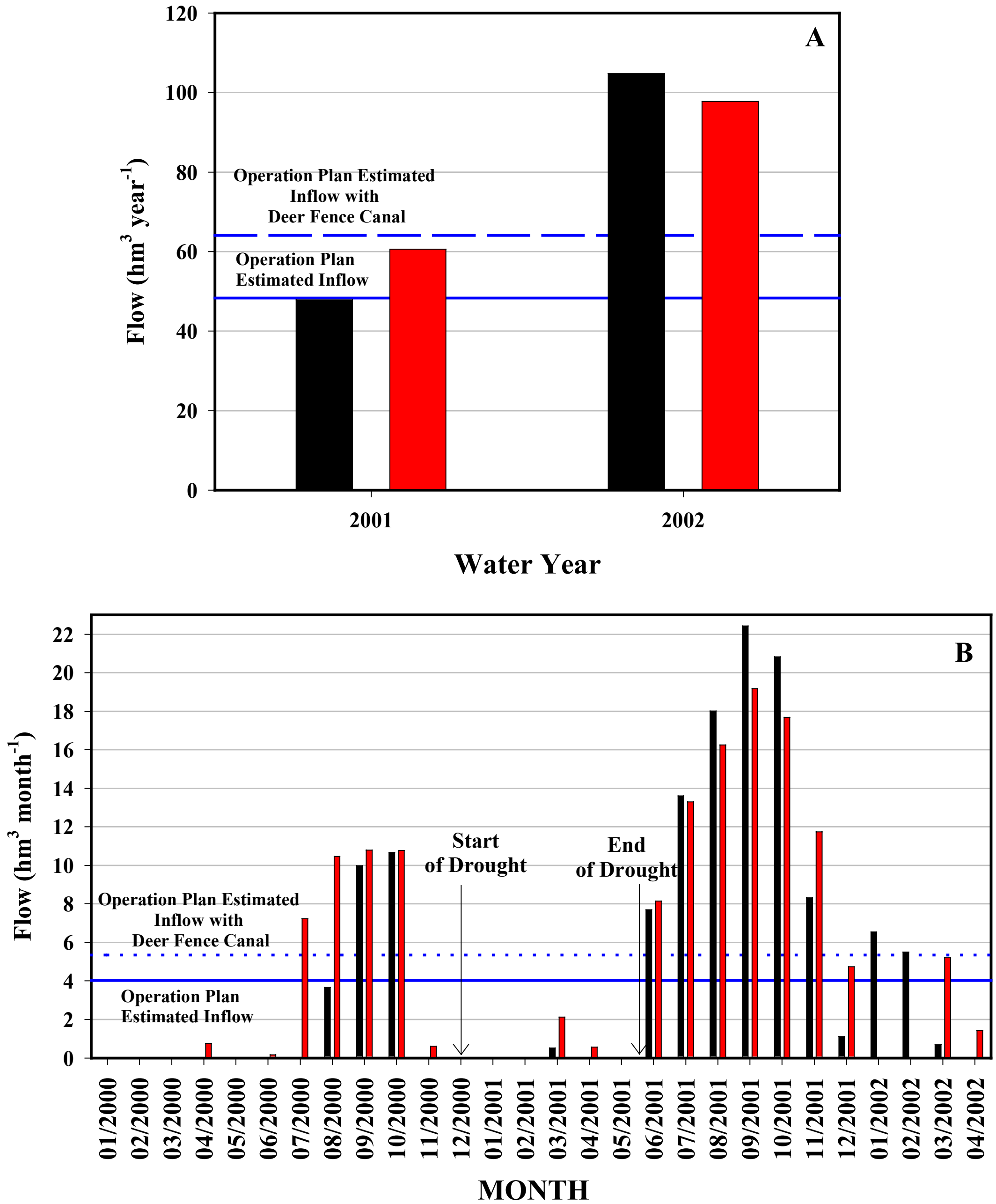

Figure 4B-7. Inflow into the northern and southern flow paths in STA-5 for WY00-01 and WY01-02. Yearly operational inflows expressed as monthly values are for reference only and do not reflect design assumptions.

Water Quality Performance

The mean inflow TP into STA-5 for WY01-02 was 163 µg/L, however the mean inflow TP concentration of 175 µg/L into the southern flow path was significantly greater than the mean inflow TP concentration of 150 µg/L entering the southern (**Table 4B-4**). This difference was primarily due to additional water that the southern flow path receives from the Deer Fence Canal, which had significantly higher inflow SRP values of 109 µg/L, compared to 85 µg/L for the northern flow-way. However, both northern and southern flow paths had significantly increased TP concentrations relative to WY00-01, with the difference. This difference in inflow concentrations was directly attributable to an increase in inflow SRP concentrations during WY01–02 over WY00–01.

Table 4B-4. Mean inflow and outflow phosphorus concentrations in grab samples collected from the northern and southern flow-ways in STA-5 for water years 2000-2001 and 2001-2002. District water years extend from May 01 through April 30 of the next calendar year. Standard deviations are presented in parenthesis.

Flow-way	Location	P Concentrations (µg/L)							
		Water Year 00-01				Water Year 01-02			
		SRP	PP	DOP	TP	SRP	PP	DOP	TP
Northern	Inflow	47 (0.04)	52 (0.07)	14 (0.01)	113 (0.09)	85 (0.07)	51 (0.03)	14 (0.01)	150 (0.08)
	Outflow	34 (0.06)	106 (0.09)	28 (0.01)	168 (0.12)	25 (0.03)	14 (0.01)	14 (0.00)	53 (0.03)
Southern	Inflow	73 (0.05)	49 (0.04)	14 (0.00)	136 (0.07)	109 (0.08)	53 (0.06)	13 0.01)	175 (0.11)
	Outflow	52 (0.06)	65 (0.06)	22 (0.01)	139 (0.09)	63 (0.04)	18 (0.02)	12 (0.01)	93 (0.04)
STA-5.	Inflow	60 (0.05)	51 (0.06)	14 (0.01)	125 (0.08)	97 (0.07)	52 (0.04)	14 (0.01)	163 (0.10)
	Outflow	43 (0.06)	86 (0.07)	25 (0.01)	154 (0.11)	44 (0.03)	16 (0.02)	13 (0.01)	73 (0.04)

The northern flow-way had a significantly lower mean outflow TP concentration during WY01-02 than the southern flow path, with concentrations of 53 µg/L and 93 µg/L, respectively (**Table 4B-4**). The mean percent TP reduction was greater from the northern treatment cells than from the southern flow-way, with reductions of 65 and 47 percent, respectively. Additionally, the individual cell performance during WY01-02 was an improvement over the previous WY00-01, in which the mean TP outflow concentrations from the northern flow-way exceeded mean inflow TP concentrations, and the southern flow-way achieved no net TP concentration reduction, with outflow TP concentrations about equal to inflow TP concentrations. In WY00–01 both flow-ways reduced SRP concentrations, but outflow DOP and PP levels exceeded corresponding inflow concentrations.

Inflow TP mass was higher for the southern flow-way compared to the northern flow-way during both WY00–01 and WY01–02; the mass of TP delivered to both flow-ways was markedly higher in WY01–02 than in WY00–01 (**Table 4B-5**). The percent mass TP retention of the northern flow-way was less than for the southern flow-way during both WY00–01 and WY01–02, but the northern flow-way reflected a substantial improvement in TP retention from WY00–01 to WY01–02, with an increased percent retention from 22 to 55 percent, respectively. The southern flow-way percent TP mass retention was 83 percent during WY00–01, but decreased slightly to 79 percent during WY01–02. However, the actual mass retained by the southern flow-way during WY01–02 was about 21,267 kg, which is slightly more than double the 10,070 kg TP retained by the same treatment cells during the previous water year.

Table 4B-5. Yearly inflow and outflow total phosphorus mass values for the northern and southern flow paths of STA-5 for water years 2000–2001 and 2001–2002. District water years extend from May 01 through April 30 of the next calendar year.

Flow-Way	Location	Water Year 00-01 (kg/yr)	Water Year 01-02 (kg/yr)
Northern	Inflow	5,209	23,436
	Additional Inflows*	1,114	912
	Total Inflows	6,323	24,348
	Outflow	4,901	10,482
	TP Retention	22%	57%
Southern	Inflow	11,362	26,231
	Additional Inflows*	653	561
	Total Inflows	12,015	26,792
	Outflow	1,945	5,525
	TP Retention	83%	79%
Percent TP Reduction for STA-5		58%	68%

* Additional Inflows include G-349A and Supplemental Pump (cell 1B) for Northern Flow-Way and G-350A for Southern Flow-Way.

The total mass P loaded into STA-5 during WY01-02 was 50,228 kg, which was about double the design P load of 25,300 kg, and 50 percent greater than the estimated P load of 33,600 kg anticipated from the addition of the Deer Fence Canal (**Table 4B-5**). The southern flow-way received more twice the P load of the northern flow-way during WY00-01, with loads of 12,015 kg P, and 6,323 kg P, respectively. During WY01-02, while both flow-ways were significantly over burdened, the P load was more equally distributed, with the Northern flow way receiving 24,348 kg P, and the Southern flow path receiving 26,792 kg P. Additionally, the majority of TP was delivered to STA-5 during the wet season (June through November) **(Figure 4B-8**).

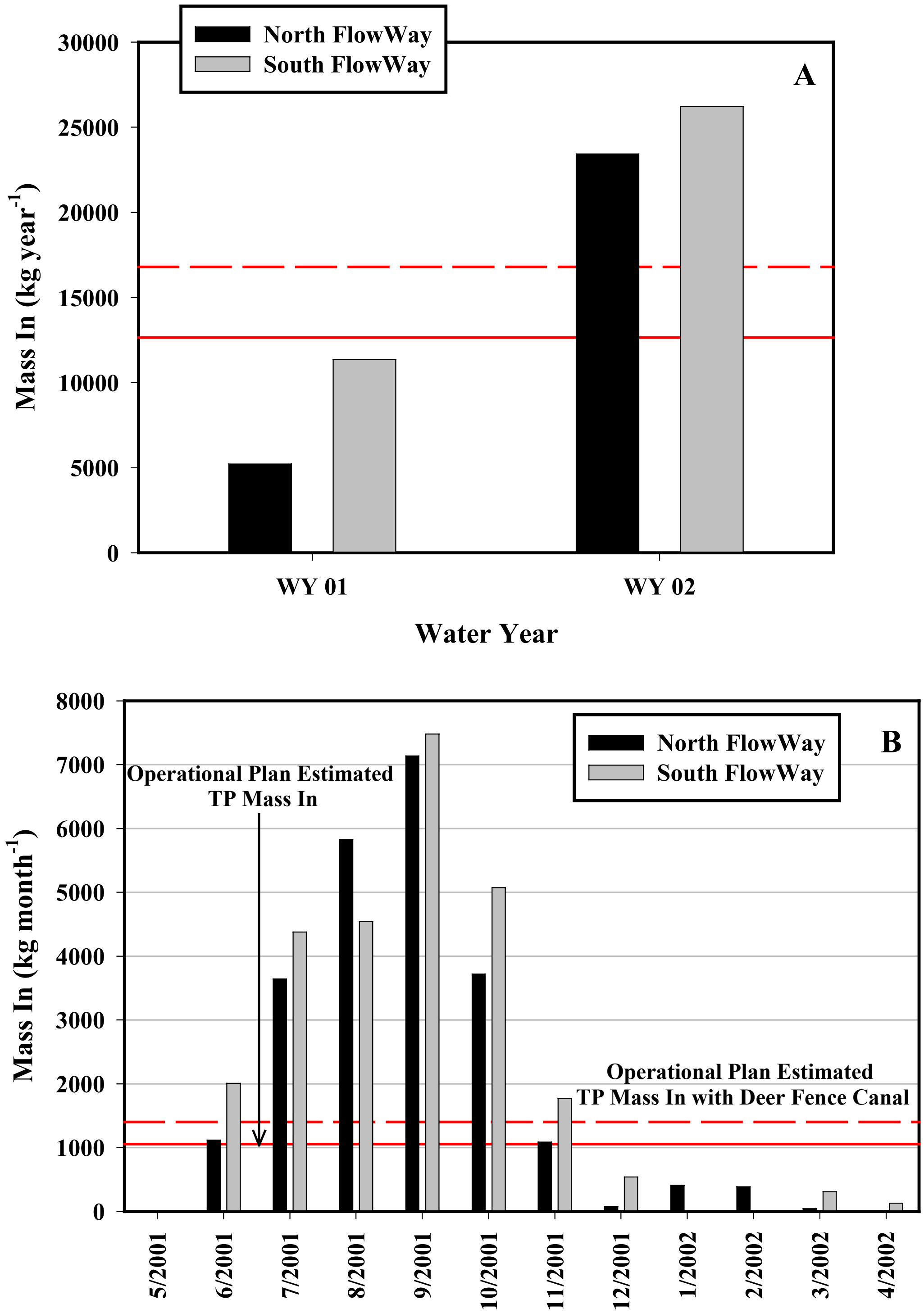

Figure 4B-8. Mass TP into the northern and southern flow paths in STA-5 for WY00-01 and WY01-02. Yearly operational inflows expressed as monthly values are for reference only and do not reflect design assumptions.

Vegetation

In June 2001, the District initiated a six-month study to monitor the recovery of STA-5 vegetation following the severe drought experienced in WY00-01. The drought conditions in WY01-02 resulted in drier soils in STA-5, cells 1A, 2A and 2B, which stressed some of the aquatic vegetation communities and allowed upland species, such as dog fennel (*Eupatorium compositifolium*), to invade sections of these cells. Six months after re-hydration (October 2001), STA-5, cells 1A and 2B exhibited the greatest diversity of aquatic plant communities, while STA-5, cell 1B exhibited the least diversity. **Table 4B-6** lists the four most common species found in each of the treatment cells six months after re-hydration. Water lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*) dominated the northern flow-way, while cattail and small floating aquatics, such as *Salvinia minima* and *Lemna valdivianna,* dominated the southern flow-way. Additionally, hydrilla (*Hydrilla verticillata*) was found at northern sampling sites, but not at the southern flow-way. After the drought, cattail coverage increased in all cells, ranging from twice the pre-drought areal coverage in STA-5, cell 2B to five times the previous areal in STA-5, cell 1A. In general, SAV contained the highest tissue TP, TN, and TC concentrations, followed by water hyacinth, and then cattail.

Table 4B-6. Dominant vegetation based on percent cover estimates from 48 sites located in STA-5, cells 1A, 1B, 2A, and 2B in October 2001.

	Dominant Species >5%			
Treatment Cell	**Most Common** →			**Least Common**
Cell 1A	*Pistia stratiotes*	*Eichhornia cras-sipes*	*Typha sp.*	*Hydrilla verticillata*
Cell 1B	*Pistia stratiotes*	*Eichhornia cras-sipes*	*Hydrilla verticillata*	*Najas guadalupen-sis*
Cell 2A	*Typha spp.*	*Salvinia minima* *Lemna valdivianna*	*Polygonum spp.*	*Pistia stratiotes*
Cell 2B	*Salvinia minima* *Lemna valdivianna*	*Typha spp.*	*Pistia stratiotes*	*Eichhornia cras-sipes*

SUMMARY

In general, STA-5 was overloaded relative to the design TP monthly load, which may explain the higher-than-design-target outflow concentration for the southern flow-way. However, despite this overloading, both the northern and southern flow-ways removed more P mass during WY01–02 than in the previous year, with TP mass retention of 57 and 79 percent, respectively. During WY01–02, STA-5 obligate wetland vegetation rebounded relatively quickly after the drought, and within six-months of re-hydration almost all invasive upland species had died. During this period, cell 1B became dominated with floating aquatics as opposed to SAV, and hydrilla was more extensive in areal coverage than *Najas guadalupensis*.

FUTURE MONITORING

In an effort to 1) increase operational knowledge of STA-5, 2) provide data to support long-term P removal models, 3) and better enhance the operation and P removal processes functioning within STA-5, the District will continue biweekly water quality monitoring of each treatment cell. Additionally, the number of internal vegetation and soil-monitoring sites has been increased. The District is in the process of obtaining ground elevation data to prepare a topographic map of STA-5. These data will aid in reducing the error in the storage volume estimates and will increase the accuracy of future hydraulic models.

PERFORMANCE EVALUATION OF STA-6

STA-6, section 1 (hereafter referred to as STA-6), encompasses 352 ha (870 ac) and is located in the southwestern corner of the Everglades Agricultural Area (EAA) adjacent to the Rotenberger Wildlife Management Area (**Figure 1-1**). Inflow into STA-6 is via a pump station (G-600) that has five 2.83 m^3/s (100-cfs) pumps (**Figure 4A-18**). The pump station is owned by U.S. Sugar Corporation and is operated based on the irrigation needs of the upstream basin (a 4,209-ha area owned by U.S. Sugar Corporation). STA-6 is divided into two treatment cells by an interior levee. STA-6, cell 3 (99 ha) receives approximately 37 percent of the stormwater inflow through a single weir (G-603), while STA-6, cell 5 (253 ha) receives the remaining inflow through two weirs (G-601 and G-602). Both treatment cells have three outflow culverts. For a detailed description of the layout and operation of STA-6, refer to the STA-6 Operation Plan (SFWMD, 2002). Current performance data are presented in Chapter 4A of the *2003 ECR*.

Since STA-6 began flow-through operations in December 1997, outflow TP concentrations have averaged about 19 µg/L, well below the design target of 50 µg/L despite the fact that the hydraulic load to this wetland has been about two-to-three times greater than anticipated. As a result, the mean hydraulic retention time for each treatment cell (STA-6, cell 3 = 5.4 days; STA-6, cell 5 = 8.5 days) (Huebner, 2002) was substantially less than those calculated for STA-1W, which ranged from 17 to 25 days. In addition to high hydraulic loading, STA-6 has experienced dryout periods ranging from two to three months each year since it began operation. In June 2001, the District has initiated a twelve-month study to evaluate the potential for nutrient release from dried STA-6 soils upon re-flooding.

HISTORICAL OPERATIONS AND SOIL TYPES

Prior to its conversion to an STA, the U.S. Sugar Corporation used the STA-6 area as a stormwater detention area from 1988 to 1997. The system had one inflow pump station (G-600) and water was distributed into the northwest section of cell 5 and moved in sheet-flow fashion from STA-6, cell 5 into STA-6, cell 3 through culverts located in the interior levee. In 1997, as part of the Everglades Construction Project (ECP), the perimeter levees were heightened and the culverts in the interior levee were closed, thereby creating two separate, parallel flow-ways. The direction of flow is now from west to east, rather than the historical north-to-south direction. The soils are classified as mucks and sands. Based on sediment core data, STA-6 has markedly lower TP, TN, TC, and organic content, as well as higher sediment bulk density than the other STAs, which is indicative of a more highly mineralized sediment. The data further suggest that STA-6 soils are stable and should not readily release P into the water column. Additional details regarding the sediment data and analyses can be found in Jorge et al. (2002).

DATA COLLECTION AND ANALYSIS

As part of the ongoing STA Optimization research program, water quality was sampled and vegetation samples were collected from STA-6 in order to fully assess, and then optimize the P-removal efficiencies of this wetland. Evaluations of overall STA-6 P-removal performance, including calculation of TP load and concentration reductions for WY01-02, are presented in Chapter 4A of the *2003 ECR*.

METHODS

Weekly composite, flow-weighted water samples are collected and analyzed for TP concentration from STA-6 inflow structure G-600 and outflow structures G-354C and G-393B for permit compliance (see Chapter 4A). In addition, biweekly grab samples are collected from these structures and are analyzed for TP, SRP, TKN, total suspended solids (TSS), turbidity, NH_4, color, DO, conductivity, pH, and temperature. Daily outflow water samples were collected for a four-week period following the annual summer dryout and were analyzed for TP concentration.

Vegetation samples were collected within STA-6, cells 3 and 5 in November 2001. Vegetation was collected from eight, one-meter-square areas within STA-6, cell 5, and from three, one-meter-square areas within STA-6, cell 3. Vegetation samples were analyzed for dry weight, ash-free dry weight, TP, TN, TC, cellulose and lignin.

Soil cores were collected from STA-6, cell 3 in September 2001 to augment soil collection done the previous year in October 2000, when soil cores were collected from STA-6, cell 5 but not from STA-6, cell 3 because water depths were too low to allow airboat access. Duplicate cores were collected from three locations in STA-6, cell 3 using a 5.1-cm diameter corer, 30-cm in length. The cores were collected and shipped on ice to the laboratory, where they were divided into 0-to-10 cm and 10-to-30 cm sections. Prior to analysis, the duplicate cores for each section were combined, and each section was analyzed for bulk density, TP, TN, TC, percent moisture and loss on ignition. Additionally, the 0-to-10 cm sections were analyzed using the inorganic P fractionation scheme (White and Reddy, 2001).

Standard weir equations and pump performance curves were used in calculating the daily average flow rates (Huebner, 2002). Mean daily inflow at inlet weirs G-601, G-602 and G-603, and at outlet weirs G-354A through C and G-393B, were computed using the standard weir equations primarily based on changes in stage data. Inflow rates of pump G-600 were computed using the stage data along with recorded motor speed. Seepage was estimated using seepage coefficients, the length of the seepage boundary, and hydraulic head difference. Cell depths were computed based on stage elevations (NGVD) minus nominal cell elevations (NGVD).

RESULTS

Average annual hydrologic performance and annual TP water concentrations for WY01-02 can be found in Chapter 4A of the *2003 ECR*.

Hydraulic Performance

Mean annual water depths for WY01-02 were 49.4 cm and 47.4 cm for STA-6, cells 3 and 5, respectively. However, the mean water depths during the wet season (June through October) were

60.0 cm and 57.2 cm for STA-6, cells 3 and 5, respectively, which were greater than the mean water depths during the dry season (November through May) (**Table 4B-7**). Inflow into STA-6, cell 5 during WY01-02 was 40.7 hm^3, which was greater than the 25.9-hm^3 inflow into STA-6, cell 3. These inflow values, expressed as HLR, were 4.4 cm/d and 7.1 cm/d for STA-6, cells 5 and 3, respectively. The outflow from STA-6, cell 5 during WY01-02 was also greater than from STA-6, cell 3, with outflow values of 35.2 hm^3) and 17.9 hm^3, respectively. The overall estimated seepage volume calculated for STA-6 was 13.5 hm^3. The seepage rate from STA-6, cell 5 was about three times greater than from STA-6, cell 3; with seepage from STA-6, cell 5 representing about 26 percent of the surface inflow volume received by STA-6, cell 5 (Huebner, 2002).

Table 4B-7. Average water depth in STA-6 during water year 2001–2002.

Treatment Cell	WY01-02 (cm)	Wet Season (cm)	Dry Season (cm)
Cell 3	49.4	60.0	41.8
Cell 5	47.4	57.2	40.4

Re-hydration Response

Two dryouts occurred during WY01-02, when nominal cell water depths were less than or equal to zero. The first dryout began in March 2001 following a prolonged period of drought, while the second dryout began in May 2001. Rainfall totaled 13.1 cm during the first dryout and 33.2 cm during the second dryout. The mean inflow TP concentration during the first re-hydration period following the dryout was 149 µg/L, which was about equal to the mean inflow TP concentration of 151 µg/L during the second rehydration period. Mean outflow TP concentration was 85 µg/L during the first rehydration and 51 µg/L during the second rehydration.

Vegetation

Field observations indicated that STA-6, cells 3 and 5 were dominated by emergent vegetation. Sawgrass (*Cladium jamaicense*) and willow (*Salix* spp.) dominated STA-6, cell 3, with isolated stands of pickerelweed (*Pontederia cordata*), duck potato (*Sagittaria spp.*), and milk vine (*Mikania* sp.). STA-6, cell 5 was dominated by paragrass (*Brachiaria purpuranscens*), torpedo grass (*Panicum repens*), and switch grass (*Panicum virgatum*), with scattered areas of cattail, other emergent species, and open water with dense floating periphyton mats. This vegetation assemblage is most likely a result of the mineral sediment, low mean TP inflow concentrations, and intermittent operation of STA-6.

Sediment

Overall, the mean bulk densities for the 10 to 30 cm core sections ranged from 0.3 g/kg to 1.3 g/kg, but there were no significant differences among cells or core sections (**Table 4B-8**). All sediment nutrient values were corrected for bulk density and were reported as mass of nutrient per unit volume of sediment to enable comparisons. Mean sediment TP concentrations from the top 10 cm of STA-6, cell 3 was 79.1 kg/m^3, which was not significantly less than the mean con centration of 106.8 kg/m^3 found in the upper section of STA-6, cell 5 (**Table 4B-8)**. Additionally, there were no significant differences among the sections or cells for the TN and TC sediment concentrations within STA-6. Yearly sediment samples of the upper 10-cm of STA-6 will be collected and analyzed for nutrient content in an effort to quantify the long-term nutrient storage of the system.

Table 4B-8. Mean nutrient data from sediments collected in STA-6. cell 5 was sampled in October 2000 and cell 3 was sampled in September 2001. Standard deviations are presented in parenthesis.

	0-10 cm Core Section		10-30 cm Core Section	
Parameter	**Cell 3**	**Cell 5**	**Cell 3**	**Cell 5**
% Moisture	71.5 (14.8)	58.8 (10.9)	44.0 (14.8)	33.0 (10.3)
Bulk Density (g/cm^3)	0.3 (0.2)	0.5 (0.2)	0.8 (0.3)	1.3 (0.3)
TP (kg/m^3)	79.1 (11.7)	106.8 (24.6)	87.9 (17.5)	77.0 (25.7)
TN (kg/m^3)	5.3 (2.5)	6.2 (1.8)	5.8 (2.5)	5.4 (1.4)
TC (kg/m^3)	66.9 (27.0)	81.7 (22.1)	66.6 (26.1)	74.9 (22.8)
Loss on Ignition (%)	42 (26)	22 (11)	20 (15)	7 (5)

SUMMARY

The overall estimated seepage from STA-6 was about 19 percent. Relative to individual cell inflow rates, estimated seepage from STA-6, cell 5 was 26 percent, which is about twice the seepage rate calculated for STA-6, cell 3 (12 percent). While STA-6, cells 3 and 5 were both dominated by emergent vegetation, sawgrass dominated STA-6, cell 3, with little or no periphyton mats, whileSTA-6, cell 5 was dominated by paragrass, torpedo grass and dense areas of periphyton mats in the open water areas. Historically, STA-6 contained a higher bulk density, more mineral sediment compared to other STAs. However, during its operation, STA-6 may be accreting an upper layer of low-density peat material.

FUTURE MONITORING

In an effort to 1) increase operational knowledge of STA-6, 2) provide data to support long-term P removal models (such as DMSTA), 3) and better enhance the operation and P removal processes functioning withinSTA-6, the District will continue biweekly water quality monitoring of the outflow from each treatment cell. In addition, the District has implemented several changes to the monitoring program in STA-6, including the installation of permanent sampling sites equipped with autosamplers at G-602 and G-603, the inflow to STA-6, cells 5 and 3, respectively; addition of Ca, alkalinity, and TDP to the list of parameters monitored in biweekly grab samples; vegetation and soil monitoring within each treatment cell; and installation of porewater wells at inflow and outflow locations in STA-6, cells 3 and 5 to measure porewater nutrients and water depth during periods of inundation and dryout.